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IDENTIFICATION AND ANALYSIS OF THE APPROACHES AND THE RISK FACTORS AFFECTING THE PERFORMANCE OF THE CONSTRUCTION WORK

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The construction industry is one of the main important industries in a nation due to its high economic impact. Yet, this industry is continuously at risk of encountering vast losses in time, cost and quality of a delivered project. Thus, to mitigate these losses, it is vital to explore the risk factors contributing at those. Various political, economic, social, technological, environmental and legal risk factors tend to affect the performance of the construction work. Thus, this paper aims to explore statistical tools and analytical approaches to identify, classify, and analyze the common risk factors that contribute to cost overrun, time overrun, and poor quality outcome. Through a systematic literature review, the main variables are abstracted and studied carefully. The variables are divided into several groups subject to their nature. Regarding the statistical tools, a meta-analysis is used to compare and analyze the different approaches used to assess the risk factors obtained from the articles. As a result, from the systematic literature review and the meta-analysis, this paper identifies the most relevant risk factors affecting the success of a construction work and the most appropriate statistical approaches.

Keywords: risk factors; assessment approaches; performance; construction; AHP

IDENTIFICACIÓN Y ANÁLISIS DE LOS MODELOS Y FACTORES DE RIESGO QUE AFECTAN AL DESEMPEÑO DE UNA OBRA

La industria de la construcción es una de las principales industrias en un país debido a su alto impacto económico. Sin embargo, esta industria tiene un riesgo elevado de incurrir en retrasos, sobrecostes y deficiencias en la calidad. Por lo tanto, para mitigar estos problemas, es vital explorar los factores de riesgo que contribuyen a ello. Diversos factores políticos, económicos, sociales, tecnológicos, ambientales y legales tienden a afectar el desempeño de la obra. Por este motivo, este documento tiene como objetivo explorar las herramientas estadísticas y los modelos analíticos para identificar, clasificar y analizar los factores de riesgo que contribuyen al sobrecoste, retraso y deficiencias en la calidad. A través de una revisión sistemática de la literatura, se extraen y analizan las principales variables. Las variables se dividen en varios grupos según su naturaleza. En cuanto a las herramientas estadísticas, se realiza un metaanálisis para comparar y analizar los diferentes enfoques utilizados para evaluar los factores de riesgo obtenidos de los artículos. Como resultado, a partir de la revisión sistemática de la literatura y el metaanálisis, este documento identifica los factores de riesgo más relevantes que afectan al éxito de una obra y los enfoques estadísticos más adecuados.

Palabras clave: factores de riesgo; modelos; desempeño; construcción; AHP

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1. Introduction

The construction industry has a large influence in the nation's economic state due to the project's dependency on large investments and asset flow. In fact, the construction sector is considered to be one of the widest and most complex in the world (Siraj & Fayek, 2019). It is due to the large number of stakeholders involved in multiple stages and entities of a construction project (Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017). Thus, this sector is always vulnerable to mistakes at any stage from any stakeholder. In fact, construction projects are exposed to an inevitable risk of losses that undermines its success (Taroun, 2014). The Project Management Institute (PMI, 2017) considers that for a project to be successful it should satisfy the iron triangle principle; it measures the success of a project by assessing its time, cost, and quality final state (PMI, 2017). Several management activities are implemented into a construction project to improve its success. Among those, risk management is mainly used to prevent losses related to risk factors. Risk factors are defined by the unexpected incidents that have a direct effect on the project's objectives (Siraj & Fayek, 2019). According to Latham (1994), risks are never prevented, they can only "be managed, minimized, shared, transferred or accepted" (Latham, 1994, p. 14). Risk factors are based on main external and internal factors which are influenced by the Political, Economic, Social, Technological, Environmental and Legal (PESTEL) sectors (Pan, Chen & Zhan, 2019). The PESTEL risk factors are identified to cause an adverse effect on the success of the project (Rastogi & Trivedi, 2016). Thus, in order to properly mitigate and alleviate losses from risk events, those risk factors should be closely identified and assessed. To identify the risk factors, a systematic literature review was made through analyzing all the possible reliable sources such as journal articles, conference papers, books, and reports related to factors having adverse reaction on the success of a project. The chosen papers were arranged in a table highlighting the risk factors considered and the assessment methods for each paper. From this table, the most frequent factors were considered for assessment. The assessment approaches were analyzed and studied according to their advantages and disadvantages in the case of building a risk model for construction projects.

2. Factors Extraction

A systematic literature review was carried out to find the most reliable sources for the collection of the risk factors affecting the success of a construction project. The papers that were focused on factors related to one or few aspects in construction were rejected. A number of 20 papers were selected according to their relevance and were arranged into groups. The grouping names (categories) were obtained implementing the affinity diagram technique (Carnevalli & Miguel, 2008).

2.1 Natural Risks

The natural risk category covers factors related to weather conditions, natural risks, acts of God, geological and ecological factors. A project can suffer delay and cost overrun if environmental events were present. Weather and climate conditions vary among rain, wind, humidity and hot climate factors. Acts of god are environmental factors that unexpectedly happen and are impossible to be stopped such as hurricanes, tornadoes, hail, and floods. Some areas such as the South East Asia have a constant encounter with floods, which makes the progress of a construction project almost impossible during a whole season (Durdyev & Hosseini, 2019). Ecological factors are related to fire, epidemics, and disease, which include everything that is related to life. Today, the world is witnessing the COVID-19 crisis, which evidently shows that every organization has been affected by this virus. Table 2 shows that

weather conditions are the natural risks with higher occurrence (15), followed by act of god (11), ecological/environmental problems (11) and geological problems (10).

Table 1. Natural Risks

	Variables	Ref.	#
NR1	Weather Conditions (rain, wind, hot climate …)	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Alkaf et al., 2012; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Enshassi, Arain, & Al-Raee, 2010; Eskander, 2018; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Kadry, Osman, & Georgy, 2017; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017; T. Wang et al., 2019)	15
NR2	Force majeure/act of god (hurricanes, tornadoes, hail, floods…)	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Kadry, Osman, & Georgy, 2017; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017)	11
NR3	Ecological/Environmental problems (fire, epidemics, disease, pollution…)	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Alkaf et al., 2012; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Kadry, Osman, & Georgy, 2017; Siraj & Fayek, 2019; Zou, Zhang, & Wang, 2007)	11
NR4	Geological problems (soil problems, earthquake, landslide, volcanic eruptions…)	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Kadry, Osman, & Georgy, 2017; Siraj & Fayek, 2019; Szymański, 2017)	10

2.2 Design Risks

Design risks are vital factors that adversely affects the success of a project. The design phase of a construction process includes the contractual stage and the design plans stage. In cases of complex construction projects, designers tend to miss and fault many details in both phases, which can lead to time overrun, cost overrun and low quality (Yap & Cheah, 2019). Insufficient information or any fault in the contract between two entities or withing the construction plans can cause disputes or errors in the following stages of the project (Zhang, 2011). Table 3 shows that design risks have a minimum occurrence of 14.

Table 2. Design Risks

	Variables	Ref.	#
DR1	Inadequate specifications and contract flaws	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Enshassi, Arain, & Al-Raee, 2010; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gupta & Thakkar, 2018; Kadry, Osman, & Georgy, 2017; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017; T. Wang et al., 2019; Yap & Cheah, 2019)	16

DR2	Incomplete and defective design	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Alkaf et al., 2012; Bahamid et al., 2020; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Enshassi, Arain, & Al-Raee, 2010; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Kadry, Osman, & Georgy, 2017; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017)	15
DR3	Inadequate site information	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Chandra, 2015; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Enshassi, Arain, & Al-Raee, 2010; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Kadry, Osman, & Georgy, 2017; Khan & Gul, 2017; Siraj & Fayek, 2019; Zou, Zhang, & Wang, 2007)	14
DR4	Changes in specifications and design	(Alkaf et al., 2012; Bahamid et al., 2020; Chandra, 2015; Durdyev, Omarov, & Ismail, 2017; El-Sayegh, 2008; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017; T. Wang et al., 2019; Zou, Zhang, & Wang, 2007)	4 1

2.3 Resources Risks

Construction projects are highly dependent on labor, equipment and material. According to Mpofu et al. (2017), there is a huge demand of worker forces in Kuwait, UAE and Qatar, due to the large amount of projects under construction at the same time. For instance, it caused those countries to have a lack on the labor availability, which lead to a decrease in the overall productivity of the projects (Mpofu et al., 2017). Construction equipment assists manpower in heavy work such as asphalting, backfilling, excavation and coring. Thus, the lack of functional equipment that are required to heavy works can cause around 5% time overrun (Zakeri et al., 1996). Material is an essential factor in the construction projects and they are determined in the design contractual phase. “The construction process is all about transforming a conceptual (architectural) design into a physical facility, which is impossible without the adequate construction materials” (Durdyev & Hosseini, 2019). Table 4 shows that within resources risks, labor productivity and availability, equipment availability and material availability are the most frequent factors.

Table 3. Resources Risks

Variables		Ref.	#
		Labor Related	
RR1	Productivity	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Alkaf et al., 2012; Bahamid et al., 2020; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017; C. Wang et al., 2019; T. Wang et al., 2019; Yap & Cheah, 2019; Zou, Zhang, & Wang, 2007)	16

RR2	Availability	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017; T. Wang et al., 2019; Yap & Cheah, 2019; Zou, Zhang, & Wang, 2007)	15
RR3	Accidents	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Alkaf et al., 2012; Bahamid et al., 2020; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Siraj & Fayek, 2019; Szymański, 2017; Zou, Zhang, & Wang, 2007)	11
		Equipment Related	
RR4	Availability	(Adeleke et al., 2018; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Enshassi, Arain, & Al-Raee, 2010; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Kadry, Osman, & Georgy, 2017; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017; C. Wang et al., 2019; T. Wang et al., 2019; Yap & Cheah, 2019)	16
RR5	Malfunction and maintenance	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Bahamid et al., 2020; Durdyev & Hosseini, 2019; Eskander, 2018; Gündüz, Nielsen, & Özdemir, 2013; C. Wang et al., 2019; Yap & Cheah, 2019)	8
RR6	Quality	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Bahamid et al., 2020; Durdyev & Hosseini, 2019; 2010; Gündüz, Nielsen, & Özdemir, 2013; Szymański, 2017; Yap & Cheah, 2019;)	7
		Material Related	
RR7	Availability	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Alkaf et al., 2012; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Enshassi, Arain, & Al-Raee, 2010; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017; T. Wang et al., 2019)	16
RR8	Delivery	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Alkaf et al., 2012; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Kadry, Osman, & Georgy, 2017; Siraj & Fayek, 2019; Szymański, 2017; Zou, Zhang, & Wang, 2007)	12
RR9	Quality	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Bahamid et al., 2020; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Eskander,	9

		2018; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Siraj & Fayek, 2019; Szymański, 2017)	
RR10	Storage allocation and damage	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; Eskander, 2018; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Szymański, 2017)	8

2.4 Financial Risks

The financial factors that tend to have an adverse effect on the success of a project are exchange rate fluctuation and inflation, financial capability, interest rate, taxes, and cost estimation and control. According to Siraj & Fayek (2019), the factor that mostly affect project cost overrun and time overrun are the financial factors. The inflation of the material and labor cost can significantly increase the cost of the project (Wang et al., 2019). Another financial factor that has a similar effect on the project success is the exchange rate. After analyzing the most frequent factors, table 5 shows that financial capability is highlighted in all the papers and exchange rate fluctuation and inflation is considered in 18 papers.

Table 4. Financial Risks

Variables		Ref.	#
FR1	Financial capability	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Alkaf et al., 2012; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Enshassi, Arain, & Al-Raee, 2010; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Kadry, Osman, & Georgy, 2017; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017; C. Wang et al., 2019; T. Wang et al., 2019; Yap & Cheah, 2019; Zou, Zhang, & Wang, 2007)	20
FR2	Exchange rate fluctuation and inflation	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Enshassi, Arain, & Al-Raee, 2010; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Kadry, Osman, & Georgy, 2017; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017; T. Wang et al., 2019; Yap & Cheah, 2019; Zou, Zhang, & Wang, 2007)	18
FR3	Cost estimation and control	(Alkaf et al., 2012; Bahamid et al., 2020; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Kadry, Osman, & Georgy, 2017; Szymański, 2017; C. Wang et al., 2019; Yap & Cheah, 2019; Zou, Zhang, & Wang, 2007)	12
FR4	Interest rate	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Alkaf et al., 2012; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Enshassi, Arain, & Al-Raee, 2010; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Kadry, Osman, & Georgy, 2017; Khan & Gul, 2017; Siraj & Fayek, 2019;	6

		Szymański, 2017; C. Wang et al., 2019; T. Wang et al., 2019; Yap & Cheah, 2019; Zou, Zhang, & Wang, 2007)	
FR5	Taxes	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Bahamid et al., 2020; Enshassi, Arain, & Al-Raee, 2010; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Siraj & Fayek, 2019)	6

2.5 Legal and Regulation Factors

These factors are requirement of permits and their approval and noncompliance to or change in laws, regulations and design standards. Officials always update rules and regulations. Thus, if not well followed, permits and project standards can cause a significant effect on the success of a project (Adeleke et al., 2018). They can be rejected multiple times before the final approval. Thus, both legal factors are pointed out in most of the papers (Table 6).

Table 5. Legal Risks

Variables		Ref.	#
LR1	Noncompliance to or change in laws, regulations and design standards	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Alkaf et al., 2012; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Enshassi, Arain, & Al-Raee, 2010; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017; Yap & Cheah, 2019)	16
LR2	Requirement of permits and their approval	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Alkaf et al., 2012; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Eskander, 2018; Gündüz, Nielsen, & Özdemir, 2013; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017; T. Wang et al., 2019; Zou, Zhang, & Wang, 2007)	14

2.6 Political Risk Factors

Political instability, bribery, corruption, terrorism, war and revolutions are all parts of the political factors. Yap and Cheah (2019) state that political instability cause lack of resources in construction projects. According to Georgy et al. (2017) war in Palestine and Afghanistan are the cause of low workforce availability which affects the time overrun of the construction project (Al-Raee et al., 2010). Despite all the factors mentioned in Table 7 can affect project cost overrun and time overrun, political instability is the most frequent.

Table 6. Political Risks

Variables		Ref.	#
PR1	Political instability	(Adeleke et al., 2018; Alkaf et al., 2012; Bahamid et al., 2020; Durdyev & Hosseini, 2019; Enshassi, Arain, & Al-Raee, 2010; Eybpoosh, Dikmen, & Birgonul, 2011; Gupta & Thakkar, 2018; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017; T. Wang et al., 2019; Yap & Cheah, 2019)	12

PR2	Terrorism, war, revolutions	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Bahamid et al., 2020; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Kadry, Osman, & Georgy, 2017; Khan & Gul, 2017; Siraj & Fayek, 2019)	11
PR3	Disputes and strikes	(Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Eskander, 2018; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Kadry, Osman, & Georgy, 2017; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017)	11
PR4	Neighbor or community problems	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Durdyev & Hosseini, 2019; Eskander, 2018; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Kadry, Osman, & Georgy, 2017; Siraj & Fayek, 2019)	7
PR5	Bribery and corruption	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Bahamid et al., 2020; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Kadry, Osman, & Georgy, 2017; Siraj & Fayek, 2019; Szymański, 2017)	7

2.7 Construction Risk Factors

Table 8 shows the construction risks factors, which are listed in order of occurrence: site conditions (i.e. access, storage, obstructions, traffic and security), new technology, supervision and inspection, security and safety, structure damage and rework, construction method, and project size and complexity.

Table 7. Construction Risks

Variables		Ref.	#
CR1	Site conditions (i.e. access, storage, obstructions, traffic and security)	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Eskander, 2018; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Kadry, Osman, & Georgy, 2017; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017)	13
CR2	New technology	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; Gündüz, Nielsen, & Özdemir, 2013; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017; C. Wang et al., 2019; T. Wang et al., 2019)	11
CR3	Supervision and inspection	(Adeleke et al., 2018; Alkaf et al., 2012; Bahamid et al., 2020; Durdyev & Hosseini, 2019; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Siraj & Fayek, 2019; Szymański, 2017; C. Wang et al., 2019; Yap & Cheah, 2019; Zou, Zhang, & Wang, 2007)	11
CR4	Security and safety	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; Enshassi, Arain, & Al-Raee, 2010; Eybpoosh,	10

		Dikmen, & Birgonul, 2011; Kadry, Osman, & Georgy, 2017; Szymański, 2017; Zou, Zhang, & Wang, 2007)	
CR5	Structure damage and rework	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Bahamid et al., 2020; Durdyev & Hosseini, 2019; Eskander, 2018; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Khan & Gul, 2017; Siraj & Fayek, 2019)	8
CR6	Construction method	(Adeleke et al., 2018; Bahamid et al., 2020; Durdyev & Hosseini, 2019; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Siraj & Fayek, 2019;)	6
CR7	Project size and complexity	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Bahamid et al., 2020;Chandra, 2015; Durdyev & Hosseini, 2019; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Siraj & Fayek, 2019)	6

2.8 Project Management Risk Factors

According to PMI (2017), project management is a studied milestone plan for the whole construction stages including obstacles that the project might encounter. Poor project cost management, poor project quality management, poor human resources management, poor communication management, poor project risk management, poor procurement management are all essential in the construction industry. As Table 9 shows, the most frequent factor is poor decision-making management. It is focused on the delay to make those decisions and the level of suitability of those decisions (Birgonul et al., 2011).

Table 8. Project Management Risks

Variables		Ref.	#
PMR1	Poor decision making management	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Alkaf et al., 2012; Bahamid et al., 2020; Chandra, 2015; Durdyev & Hosseini, 2019; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Kadry, Osman, & Georgy, 2017; Siraj & Fayek, 2019; C. Wang et al., 2019; Zou, Zhang, & Wang, 2007)	13
PMR2	Poor project quality management	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Alkaf et al., 2012; Chandra, 2015; Durdyev & Hosseini, 2019; Eskander, 2018; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Kadry, Osman, & Georgy, 2017; Siraj & Fayek, 2019; C. Wang et al., 2019; Yap & Cheah, 2019)	12
PMR3	Poor project cost management	(Bahamid et al., 2020; Durdyev & Hosseini, 2019; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Kadry, Osman, & Georgy, 2017; Siraj & Fayek, 2019; Szymański, 2017; C. Wang et al., 2019; T. Wang et al., 2019; Yap & Cheah, 2019; Zou, Zhang, & Wang, 2007)	12

PMR4	Poor communication management	(Bahamid et al., 2020; Durdyev & Hosseini, 2019; Enshassi, Arain, & Al-Raee, 2010; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Gupta & Thakkar, 2018; Khan & Gul, 2017; Siraj & Fayek, 2019; Szymański, 2017; C. Wang et al., 2019)	10
PMR5	Poor procurement management	(Abd El-Karim, Mosa El Nawawy, & Abdel-Alim, 2017; Adeleke et al., 2018; Chandra, 2015; Durdyev & Hosseini, 2019; El-Sayegh, 2008; Gündüz, Nielsen, & Özdemir, 2013; Kadry, Osman, & Georgy, 2017; Szymański, 2017; C. Wang et al., 2019; Yap & Cheah, 2019)	10
PMR6	Poor human resources management	(Chandra, 2015; Durdyev & Hosseini, 2019; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; C. Wang et al., 2019; Yap & Cheah, 2019)	6
PMR7	Poor project risk management	(Alkaf et al., 2012; Durdyev & Hosseini, 2019; Eybpoosh, Dikmen, & Birgonul, 2011; Gündüz, Nielsen, & Özdemir, 2013; Yap & Cheah, 2019)	5

3. Assessment Methods

To study the possible assessment methods, a meta-analysis was done on the same papers that the risk factors were collected from. Five methods were frequently used within those 20 papers. The assessment methods were a combination of Relative Importance Index (RII), Principal Component Analysis (PCA), Analytic Hierarchy Process (AHP), Confirmatory Factor Analysis (CFA) and Partial Least Square (PLS) with Structural Equation Modeling (SEM).

3.1 Linear Regression Using Relative Importance Index

The relative importance index method relies on finding which of the variables is most likely to affect the constructs. The relative index method works on the variables as each one independent from each other. It acts on the system as if there are no groups. However, the relative importance index measures the effect of the variables on the constructs. The variable that has the highest index is considered to be the most important one within the variables. Thus, in order to get reliable results, the data must be accurate and the sampling size should be significant. In fact, it is applied when there is a random system of variables in the field (Khan & Gul, 2017).

3.2 Linear Regression Using Principle Component Analysis

There are two main types of regression: simple regression, and multiple regression. Simple regression is used to explore the interrelation among variables and one construct. When there is more than one construct to be explored, multiple regression is used. The Principal Component Analysis (PCA) is a data-reduction technique used to identify variables that has an effect on the constructs, calculates the effect of the variables on the constructs, and estimates the effect of constructs depending on the group of variables (Yap & Cheah, 2019).

3.3 Analytic Hierarchy Process

Not very different than the relative importance index, AHP is an approach that measures all the prioritized factors and comes out with the best among them. Both Eskander (2018) and (Abdelalim, 2018) divide the possible factors into a hierarchical shape descending from general to specific. Then, “the criteria and sub-criteria used in the hierarchy can be assessed using the

AHP approach of pairwise comparison of elements in each level with respect to every parent element located one level above" (Abdelalim, 2018, p.142). The pairwise comparison identifies the most important local factors at each level of the hierarchy. Those are the main components that affect its previous level parent. Thus, AHP takes into consideration a combination of factors and not just the factor itself. The result will be the best grouping alternative that mostly affects the constructs of a research. It works on multiple levels of variables, and studies each possibility according to its intensity and reference from the collected data. It is very useful when it comes to the subjectivity and uncertainty from the construction sector.

3.4 Partial Least Square and Structural Equation Modeling

The PLS path modeling is "a family of regression based methods designed for the analysis of high dimensional data in a low-structure environment" (Dijkstra, 2010, 24). According to Adeleke et al. (2018), PLS has been used in the fields of social researches related to management of projects and business. PLS advantages over CFA is that PLS is used when the data collected has non-homogeneity variance, non-normal distribution, more than 40-50 variables, and interactions effects (Lowry & Gaskin, 2014). Partial Least Square is used by Adeleke et al. (2018) and Wang et al. (2019).

3.5 Confirmatory Factory Analysis (CFA) and Structural Equation Modeling (SEM)

CFA is a factor analysis technique, which is used in studies where societal factors are explored. SEM is a method that shows the internal relationship among the variables and the constructs. To go through SEM, the factors must first be developed, verified, and validated (Chandra, 2015). CFA's function is to develop, test, and validate the measurement according to the researcher's choice of the constructs. "It is assumed that researcher has strong knowledge of the structure of the variables" (Birgonul et al., 2011, 1167). According to Byrne (2006), SEM is the most appropriate method to study the complex interactions among variables, and verifying those variables and their interactions. Chandra (2015) and Eybpoosh et al. (2011) used CFA and SEM combined in their research.

4. Conclusions

After studying a number of 20 papers that explores the risk factors of the construction industry, 44 factors were extracted. Those 44 factors are illustrated in the tables 1-8 and divided into 8 categories explained next. Natural risk factors are weather conditions, force majeure, geological problems, and ecological problems. Design risk factors are inadequate specifications and contract flaws, incomplete and defective design, changes in specifications and design, and inadequate site information. Resources risk factors are divided into three groups: availability, productivity and accidents related to labor; availability, quality, malfunction and maintenance related to equipment; and availability, delivery, quality, storage allocation and damage related to material. Financial risk factors are exchange rate fluctuation and inflation, financial capability, interest rate, taxes, cost estimation and cost control. Legal and regulation factors are requirement of permits and their approval, and noncompliance to or change in laws, regulations and design standards. Political risks are political instability, bribery and corruption, terrorism, war, revolutions, strikes and disputes, and neighbor or community problems. Construction risks are related to site conditions, structure damage and rework, construction method, project size and complexity, supervision and inspection, security and safety, and new technology. Project management risk-related are poor project cost, quality, human resources, communication, risk, decision-making and procurement management.

After analyzing the occurrence of the risk factors, the ones that presented an occurrence of 15 or greater were: weather conditions, inadequate specifications and contract flaws, incomplete and defective design, labor productivity, labor availability, equipment availability, material

availability, financial capability, exchange rate fluctuation and inflation, and noncompliance to or change in laws, regulations and design standards. Regarding the assessment methods, the most frequently used for the assessment of the risk factors in the construction industry were CFA and PLS used along with SEM, RII and PCA regression analysis, and AHP. CFA and PLS with SEM were used to find an external and internal relationship among the independent variables and the dependent variables. RII and PCA regression analysis were used for ranking and data-reduction of the long list of variables without exploring the interconnection among the variables. AHP was used to identify the best fit group of independent variables that mostly affect the constructs.

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